SB761
U757
91-6

United States
Department of
Agriculture
**Forest
Service**
Southwestern
Region

Forest Pest Management Report

R-3 91-6

BIOLOGICAL EVALUATION OF PEST CONDITIONS
IN THE BIG LAKE MANAGEMENT COMPLEX
APACHE-SITGREAVES NATIONAL FORESTS, ARIZONA

MAY 1991

3420

R-3 91-6

BIOLOGICAL EVALUATION OF PEST CONDITIONS IN THE BIG LAKE MANAGEMENT COMPLEX APACHE-SITGREAVES NATIONAL FORESTS, ARIZONA

MAY 1991

By

Mary Lou Fairweather
and
Jill Wilson

USDA Forest Service, Southwestern Region
State and Private Forestry
Forest Pest Management
517 Gold Avenue, SW
Albuquerque, New Mexico 87102

LIBRARY COPY
ROCKY MT. FOREST & RANGE
EXPERIMENT STATION

ABSTRACT

The Arizona Zone Office of Forest Pest Management conducted a survey of 275 acres, delineated into five stands, in the Big Lake Management Complex on the Springerville Ranger District, Apache-Sitgreaves National Forests. Survey objectives were to determine distribution of insects and diseases and to use the information to recommend a location for a proposed campground facility. Diseases observed in the survey that could affect campground longevity and hazard tree development were: Root rots, dwarf mistletoes, stem decays, and aspen stem cankers. Each stand was unique in occurrence and level of these diseases. An area within Stand 5 in which the diseases can either be avoided or managed effectively was selected with District personnel for location of the proposed campground.

INTRODUCTION

In 1989, Forest Pest Management in Region 3 initiated an insect and disease incidence survey of recreation sites. These surveys were conducted to evaluate the overall "health" of proposed and existing campground areas on the National Forests. The Forest Pest Management Arizona Zone Office was requested by personnel on the Apache/Sitgreaves National Forests to evaluate 275 acres in the Big Lake Management Complex, on the Springerville Ranger District (Figure 1). The area is at 9,000 feet of elevation, and is composed of southwestern mixed conifer species. Plans were being developed for a new 125 unit, 65 acre, mini group campground. It was necessary to determine present pest conditions which may drive actual campground placement within the evaluated area.

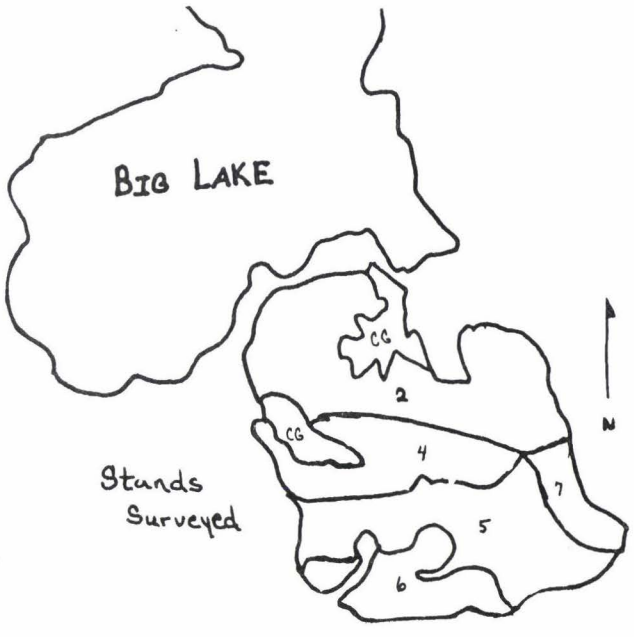

FIGURE 1. Stand delineation of the Big Lake Management Complex.

OBJECTIVES

The objectives of this survey were to evaluate and document the incidence of insect and disease activity and damages in an area proposed for campground development and to recommend a location for the proposed campground that would have minimal pest problems.

METHODS

In the summer of 1989, five separate stands, delineated by the Ranger District based on structure and species composition were surveyed. Although there are actually seven stands in the analysis area south of Big Lake (Figure 1), two of these stands (numbered 1 and 3 for identification) are existing, developed campgrounds. The five stands surveyed are numbered: 2, 4, 5, 6, and 7 for identification. The insect and disease survey was performed according to Region 3 Stage II Stand Exam Survey methods as described in the Region 3 Silvicultural Examination and Prescription Handbook (FSH 2409.26d) and as detailed for pest impacts by Terrence J. Rogers (unpublished report). The basal area (BA) factor was adjusted appropriately for each stand in order to obtain five to eight trees per variable plot. Fixed plots were 1/100th of an acre. Distance between points and lines was four chains and survey stakes were used to mark plot center.

The following data were collected for each tree recorded on the fixed and variable radius plots: Species, diameter at breast height (DBH), height, tree history, crown information, damage codes, and a dwarf mistletoe rating (DMR) (Hawksworth, 1977). Age and growth increment were determined for the first two trees on each plot.

In the spring of 1990, additional information was collected in order to obtain root disease information and map out disease centers. The original lines used in the first survey were cruised and the following information recorded for each root disease center: Location to nearest plot center (recorded in chains); size; species and DBH of live, dead, and dying trees; symptoms (pocket-like succession of dead, dying, and fading trees) and signs (fruiting bodies, white mycelial fans, rhizomorphs, resinosus, or incipient decay) of root disease for each tree; type of pathogen present; and species and approximate size of stumps. The size of the root disease center included the approximate root radius (Filip, personal communication) of border trees showing signs or symptoms of root disease. The proportion of the stand area infected was estimated from the proportion of the total transect line falling within root disease centers. The Stand Prognosis Model (Stage, 1973; Wykoff et. al., 1982) combined with the Root Disease Model (Stage et. al., 1990) was used to predict the effects of root disease on the future of the stands.

OBSERVATIONS

Area and Stand Structure Description

The area analyzed is in a blue spruce/Arizona fescue (PIPU/FEAR) habitat type, containing various combinations of aspen, Engelmann and blue spruce, Douglas-fir, ponderosa pine, southwestern white pine, and corkbark fir. Based on data collected during the Stage II stand examination, timber type was classified for each stand (Table I). Stands 5, 6, and 7 classified as

aspen stands, Stand 2 spruce-fir and Stand 4 ponderosa pine. Stands classified as aspen were not combined for analysis due to differences in species composition and pest incidence. Basal area and trees per acre (TPA) were lowest for Stand 5 (104 and 539, respectively) and greatest for Stand 7 (165 and 1281, respectively) (Table I). Basal area (trees >9" dbh) and TPA in seedling, sapling, and >9" DBH classes for each species in a stand is given in Table II. Aspen, spruce, Douglas-fir, southwestern white pine, and ponderosa pine were found in all surveyed stands (Figure 2). True fir was found only in Stands 2 and 4 and Douglas-fir was not found in the overstory of Stand 6. Depending on the stand, 4 to 36 percent of the trees were found to be infested by one or more pests (Table I).

TABLE I. Timber Type, Basal Area (BA) and Trees per Acre (TPA) of selected stands, near Big Lake, Apache-Sitgreaves National Forest.

STAND	CLASSIFICATION	BASAL AREA/AC	STEM /AC	TOTAL ACRES	% TREE DAMAGE
0002	Spruce-Fir	150	990	87	12
0004	Ponderosa	110	934	45	4
0005	Aspen	104	539	74	14
0006	Aspen	105	556	35	28
0007	Aspen	165	1281	36	36

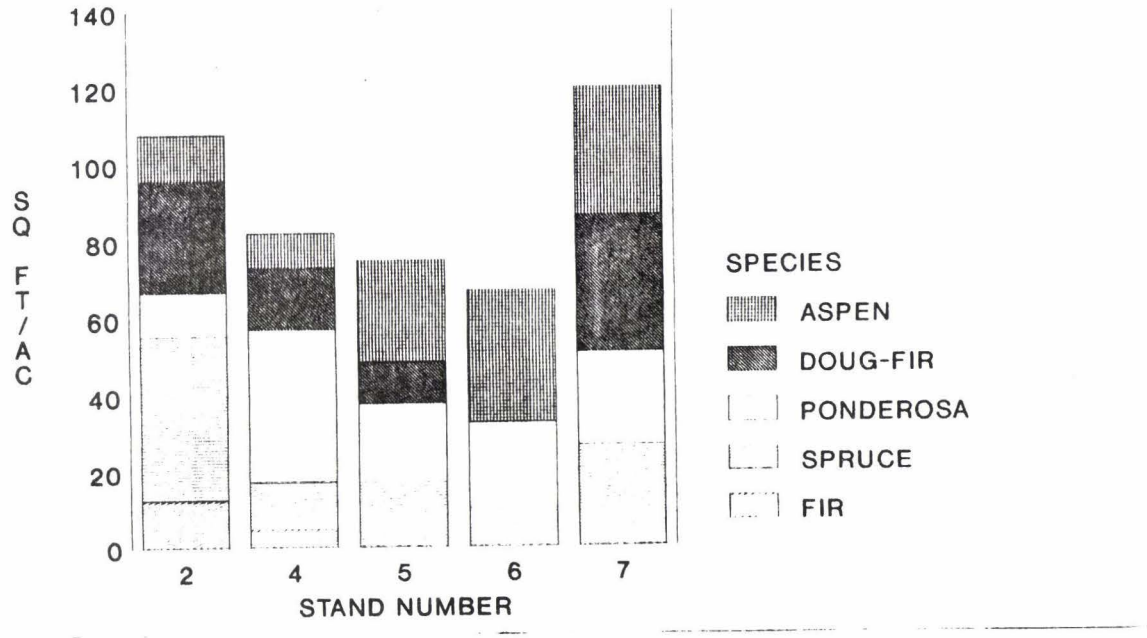

FIGURE 2. Stand Basal Areas By Species. (Trees > 9" DBH)

TABLE II. Basal area/Acre (BA), Trees/Acre (TPA), and Dwarf Mistletoe Rating (DMR) by species.

Stand/species	BA		TREES PER ACRE (TPA)						DMR
	>9" dbh[a]		<5" dbh		5"-9"dbh		>9" dbh		
STAND 2		%		%		%		%	
TRUE FIR	12.4	11	144	17	11	14	13	15	
SPRUCE	43.2	36	326	39	47	47	40	47	.3
PONDEROSA PINE	11.3	9	6	1	3	4	3	3	.1
DOUGLAS-FIR	28.8	24	212	25	9	11	13	15	.5
SW WHITEPINE[b]	12.3	10	30	4	0		6	7	
ASPEN	12.4	10	115	14	11	14	11	13	
TOTAL	120.3		833		81		86		
STAND 4									
TRUE FIR	4.7	5	44	5			5	8	
SPRUCE	12.6	14	300	36	16	53	11	17	.2
PONDEROSA PINE	40.0	43	63	7			20	30	
DOUGLAS-FIR	15.6	17	144	17	10	33	8	12	.4
SW WHITE PINE	11.0	12	131	16			8	12	
ASPEN	9.4	10	156	19	4	14	14	21	
TOTAL	93.3		838		30		66		
STAND 5									
TRUE FIR			11	3					
SPRUCE	17.0	22	74	19	40	49	23	34	.6
PONDEROSA PINE	20.8	27	28	7			11	16	
DOUGLAS-FIR	10.8	14	94	24	10	12	4	6	.6
SW WHITE PINE	1.9	2	22	6	2	2	1	1	
ASPEN	26.4	34	164	42	30	37	29	43	
TOTAL	76.9		393		82		68		
STAND 6									
TRUE FIR									
SPRUCE	10.0	15	214	57	87	84	18	23	.2
PONDEROSA PINE	22.8	34	38	10	4	4	15	20	.6
DOUGLAS-FIR			29	8					
SW WHITE PINE			10	3					
ASPEN	34.3	51	81	22	12	12	45	57	
TOTAL	67.1		372		103		78		
STAND 7									
TRUE FIR									
SPRUCE	26.6	22	444	42	63	63	34	30	.6
PONDEROSA PINE	24.4	20	22	2	3	3	17	15	1.0
DOUGLAS-FIR	35.6	29	222	21			16	14	
SW WHITE PINE	1.1	1	33	3			1	1	
ASPEN	33.4	28	345	32	34	34	45	40	
TOTAL	120.		1066		100		113		

[a] dbh = diameter at breast height
[b] Southwestern white pine

Diseases

The major diseases observed during the stand exams were: Dwarf mistletoes, root rots, stem decays, and stem cankers. Disease occurrence varied between stands due to differences in species composition and stand structure.

Dwarf Mistletoes

Dwarf mistletoes were the most prevalent diseases followed by root diseases, stem decays, and stem diseases (Figure 3). Host-specific dwarf mistletoe species (see Biology of Pests) were found infecting ponderosa pine, spruce (Engelmann and blue), and Douglas-fir. At least two of these conifer species were infected with dwarf mistletoe in each stand. Dwarf mistletoe infection was not found in true fir or southwestern white pine. Dwarf mistletoe ratings ranged from 0.1 for ponderosa pine in Stand 2 to 1.0 for ponderosa pine in Stand 7 (Table II). This translates to light (stand DMR<0.4) to severe (stand DMR>0.9) dwarf mistletoe infection. Dwarf mistletoes have the greatest impact on the future species composition of a stand where an infected overstory showers dwarf mistletoe seeds down on susceptible understory trees. In Stand 7 spruce regeneration is threatened by the spruce dwarf mistletoe: All age classes of spruce are infected; spruce stand DMR is 0.6; and spruce seedlings are abundant (444 TPA).

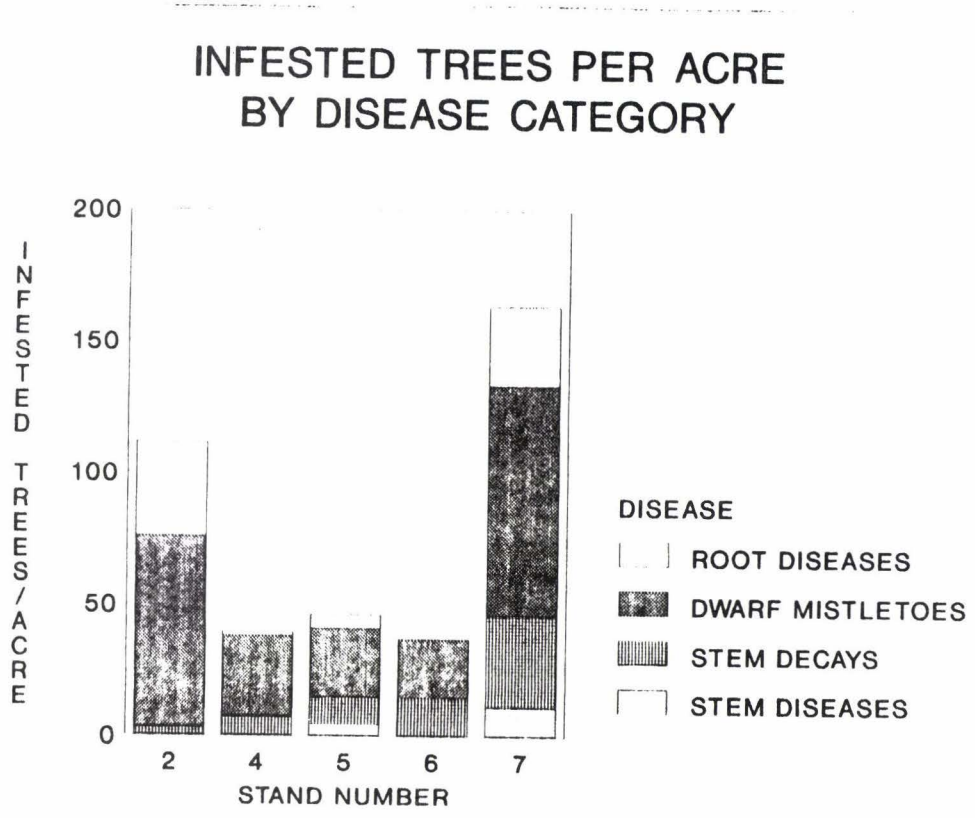

FIGURE 3. Infested Trees per Acre by Disease Category.

Root Disease

Root disease centers were identified and mapped (Figure 4) for all stands. The most common root disease was armillaria root rot (see Biology of Pests) which mainly occurred in spruce. A few annosus root disease pockets were observed on the rocky ridge of Stand 4, around large stumps (see Biology of Pests). Root disease pockets ranged from a single tree to a few acres of trees showing signs and symptoms of root disease. Table III summarizes results from the Prognosis/Root Disease Model runs. The north facing slopes of Stands 2 and 4 had the greatest percentage of acres infected (>30%). Stand 7 had the greatest number of infected trees per acre in root diseased areas, probably due to dense stocking and the larger spruce component of the stand. Although Stand 5 had the greatest number of infection centers, they were small (only one or two trees) and only 12 percent of the total acres were infected. Model predictions of future infection levels within root disease centers varied between stands. Initially Stands 2 and 4 and Stands 5 and 6 had similar numbers of infected TPA: 80 vs. 84 and 46 vs. 47, respectively. However, after 50 years the predicted number of infected TPAs for Stands 2 and 4 are 27 vs. 9, respectively, while Stands 5 and 6 were 10 vs. 13, respectively (Table III). The variability relates to the availability of hosts as affected by species composition and total trees per acre. The infected TPA of Stand 4 dropped off due to a low spruce/fir component compared to Stand 2. Stands 2 and 7 are densely stocked and have high percentages of the preferred hosts, spruce and true fir.

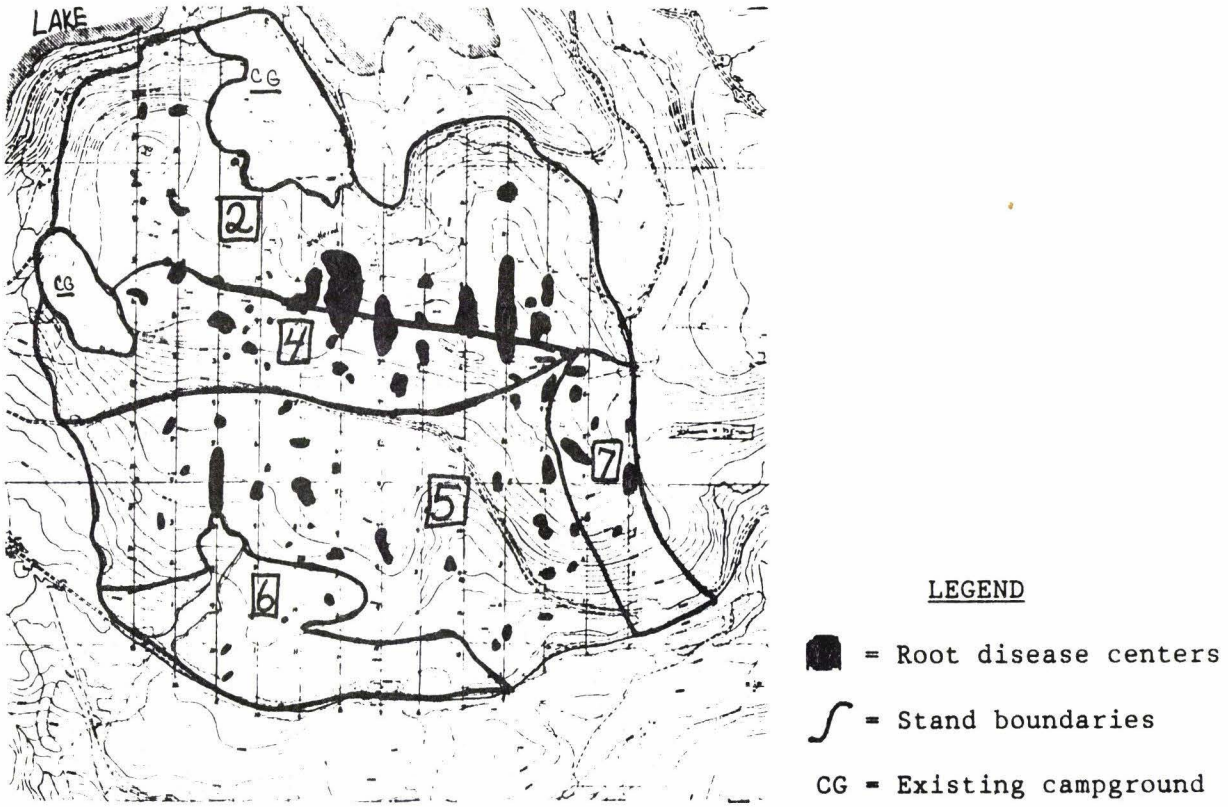

FIGURE 4. Root disease centers observed in 1990.

TABLE III.

Prognosis/Root Disease Model Current and Projected Root Disease Levels.

Stand #	# Infection Centers[a]	Acres[b] Infected 1989 (%)	2039 (%)	Total TPA[c] 1989	2039	TPA[c] Infected 1989	2039
2	20	30 (34)	45 (52)	1034	287	84	27
4	17	14 (31)	17 (38)	984	434	80	9
5	27	9 (12)	13 (18)	566	211	46	10
6	4	1 (3)	2 (6)	584	254	47	13
7	6	5 (14)	8 (22)	1281	410	104	25

[a] The number of infection centers remains the same over time.
[b] Percent of total stand acres (see Table I).
[c] TPA = Trees per acre.

The spread rate of root disease predicted from the Root Disease Model over a 50 year period (Figure 5) shows a consistent increase for Stand 2, but fluctuations for the other stands analyzed. In addition to species composition and total number of trees per acre, the spread rate is also dependent on the number of infection centers. The average percent of roots infected (set at a standard 10 percent for all stands run through the model) has little effect after one or two growth cycles (Marsden, personal communication). Given the multitude of factors involved, it is difficult to interpret fluctuations in the rate of spread. However, those stands which have high proportions of preferred host species (i.e. spruce and true fir) have high levels of infected trees per acre and high spread rates.

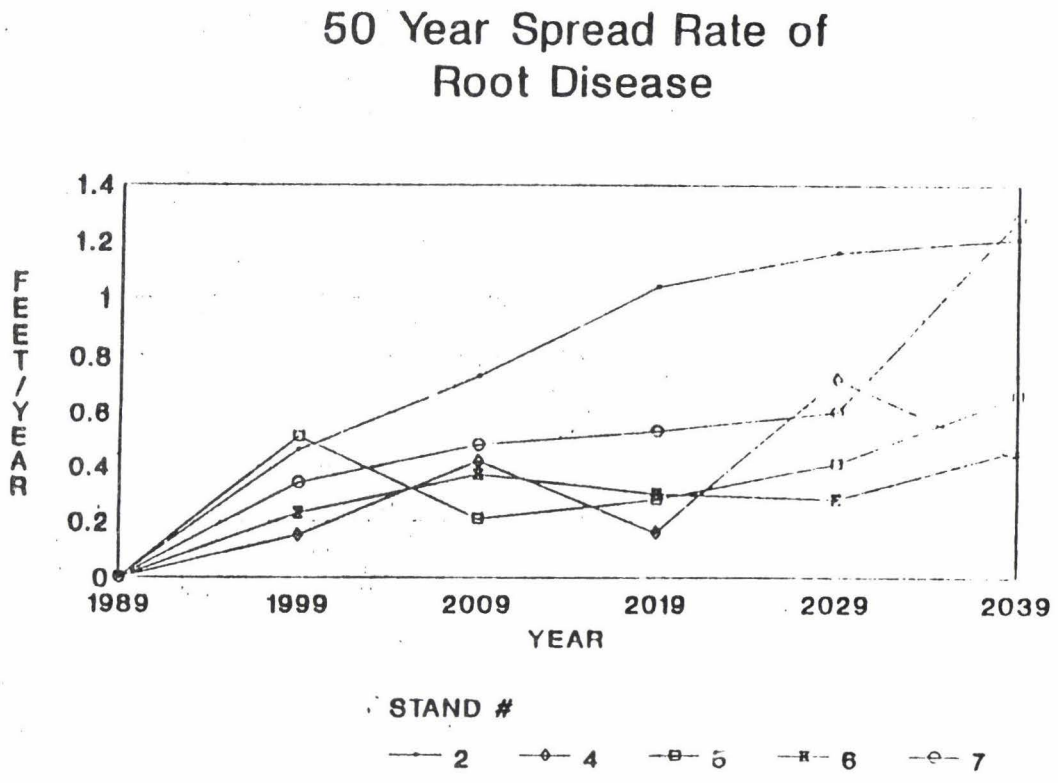

FIGURE 5. Fifty year projected spread rate of root disease of five stands in the Big Lake Management Complex.

Stem decays

The major stem decay was the false tinder conk (Phellinus tremulae) in living aspen trees (see Biology of Pests). The most common stem decay fungi in conifers were Dichomitus squalens (Red Rot) in ponderosa pine and Fomitopsis pinicola (Red Belt) in Douglas-fir (see Biology of Pests). These fungi are more commonly associated with older mature trees. Infection by decays is difficult to diagnose in live trees since most of these fungi tend to fruit on dead woody material only. Like root diseases, stem decays are common in developed recreation sites due to high incidences of wounds and advanced tree age. Decay is of greater concern in these sites than in areas managed for timber because failure of decayed trees can cause injury to people and their property.

TABLE IV.

Average Number of Dead Trees Per Acre for each Species in a Stand.

	STAND NUMBER				
SPECIES	2	4	5	6	7
TRUE FIR	1.0	nr	na	na	na
SPRUCE	10.1	8.2	2.5	.5	2.6
PONDEROSA	nr	nr	.8	5.7	1.4
DOUGLAS-FIR	4.0	4.8	nr	nr	nr
ASPEN	14.1	11.1	6.2	.8	5.0
TOTAL	29.2	24.1	9.5	7.0	9.0

nr = none recorded
na = not applicable, species did not exist in stand

Aspen Mortality

Aspen was the species with the highest mortality rate in all stands except Stand 6 (Table IV). Stands 2 and 4 had more than 20 dead trees per acre, with spruce closely following aspen. Although root disease accounts for the majority of spruce mortality, stem canker diseases were the primary cause of aspen mortality. The most common stem diseases of aspen observed in the Big Lake area were sooty bark (Encoelia pruinosa) and black canker (Ceratocystis fimbriata) (see Biology of Pests). The former may girdle and kill a tree in three to four years (Hinds and Ryan, 1985), while the latter does not girdle a tree but typically predisposes it to windbreak. The root and butt rot fungus, Ganoderma applanatum, was infrequently observed during the survey. This fungus often predisposes aspens to windthrow, as the roots are severely decayed and weakened. Like Armillaria, it also forms root disease centers.

Insects

The only insect recorded during the stand examination was the western spruce budworm. General information on this insect is included in the Biology of Pests section. Light defoliation (less than 25 percent of the crown defoliated) was observed on blue and Engelmann spruce, Douglas-fir, and corkbark fir throughout the survey area. Survey results are shown in Table V. Trees of all diameters were affected. Spruce budworm was most common in Stand 7 (34 percent of the host trees infested) and least common in Stand 4 (6 percent of the host trees infested). In general, more budworm defoliation was observed in the southern half of the surveyed area.

TABLE V.

Number and Percent of Trees Affected by Western Spruce Budworm

Stand	Trees Defoliated per Acre by Diameter Class			Total Trees per Acre	Percent Host Trees Affected
	0-4.9	5-8.9	>9		
7	211.1	34.2	21.4	266.7	34.2
6	47.6	53.8	2.7	104.1	30.0
5	20.8	18.9	11.8	30.7	12.0
4	12.5	15.4	6.4	34.4	6.4
2	32.4	18.9	10.8	62.1	7.6

A serious outbreak of western spruce budworm is not likely to occur in the survey area given current stand conditions. None of the surveyed stands have a large component of true fir or Douglas-fir, the insect's principal hosts in the southwest (Linnane, 1986). The most likely situation for the future would be occasional light defoliation.

Although other insects were not found during the stand exam, several bark beetle species and two aspen defoliators may occasionally occur in the area. Four species of bark beetles: Western pine beetle, western balsam bark beetle, spruce beetle and Douglas-fir beetle have been observed in the area (see Biology of Pests). Spruce beetle has caused some small pockets of spruce mortality (less than 10 trees per mortality center) in the vicinity of the survey area in the past. One ponderosa pine, probably killed by western pine beetle, was observed near one of the points during the survey. It is unlikely that any of these beetles would cause extensive mortality in the survey area. The present stand conditions are not conducive for outbreaks of any of these beetles. Scattered single trees, primarily the largest oldest trees, may be attacked over time.

Two species of aspen defoliators, the western tent caterpillar, and the large aspen tortrix occur in the region. A few tents of the western tent caterpillar were observed on aspen trees north of the survey area in the spring of 1989. An outbreak of either of these insects could occur and cause substantial defoliation. In that event, the main effect would be a temporary impact on visual resources. Tree mortality following outbreaks of either of these insects are rare. Defoliated trees usually leaf out again later in the summer of the year they are defoliated.

DISEASES

ASPEN DISEASES

Sooty Bark, Encoelia pruinosa. This canker-causing fungus is very aggressive, causing tree mortality within four to five years after initial infection. Disease is associated with cambial wounds; the fungus infects trunk wounds and penetrates the inner bark and cambium. The dead outer bark sloughs off two or three years after initial infection, exposing the blackened inner bark in an elliptical, zonate pattern. Spores of the fungus are formed on light-grey, cup-shaped fruiting bodies on the old, dead inner bark. Sooty-bark canker is named for the black residue formed under the infected bark that adheres tightly to the trunk for many years, even after tree death.

Black Canker, Ceratocystis fimbriata. This disease is widespread throughout the range of aspen. These cankers are also associated with wounds or natural openings in the bark. It produces black target-shaped cankers on the bole of infected trees. This fungus seldom kills trees, because it spreads a very short distance on the tree each year. Occasionally, two or more cankers may eventually kill a tree by coalescing and girdling the stem. Many Ceratocystis cankers are not associated with decay, but old cankers can weaken the tree and cause failure. Prevention of wounds on trees will reduce the incidence of this disease.

Aspen Trunk Rot, Phellinus tremulae. This disease is the most common cause of defect in aspen. Fruiting bodies or conks of this fungus are frequently found on stems of living and dead trees and often occur near branch stubs or old wounds. Conks are hoofed shaped; the upper surface is grey to black and divided into irregular squares by numerous cracks. The interior of the conk has white flecks and a layered appearance; the color of the lower surface varies from tan to white to dark brown and has many tiny pores. Trees with more than three conks above 16 feet are generally severely decayed and susceptible to windthrow at any time. This decay is most common in overmature stands; however, it can also infect young trees.

White Mottled Rot, Ganoderma applanatum. A common cause of root and butt rot of living aspen. Ganaderma applanatum is found in almost all aspen stands but is more common on moist sites with deep soils. The fruiting bodies are shelf-like structures, commonly called conks. A common name for this fungus is the "artist conk" because the tissue stains permanently when bruised, and pictures may be drawn with a sharp tool. Infections take place at wounds where the fungus attacks sapwood, heartwood and cambial tissue. Although the decay is typically concentrated in the large roots and basal part of the stem, it may extend several feet up into the main stem. This root rot is usually restricted to roots larger than 2.5 inches in diameter, indicating large roots act as avenues of spread to new hosts. Direct mortality is minimal in most stands, but susceptibility to windthrow can be extensive. Eighty-six percent of windthrown aspen trees in a stand in Colorado exhibited signs of G. applanatum at the base (Landis and Evans, 1974). Removal of infected trees is recommended to reduce hazard in recreation sites.

ROOT DISEASES

Armillaria Root Disease, Armillaria spp. Armillaria root disease, or shoestring root rot, caused by fungi in the genus Armillaria, affects several species of conifers throughout the West. All commercial tree species in the southwestern Region are susceptible, but nonresinous conifers, such as true firs and spruces, are more susceptible than Douglas-fir and ponderosa pine (Wood, 1983). Not only has susceptibility been found to vary between conifer species, but different levels of pathogenicity (ability to cause disease) of the fungus have been recognized. In the past, all Armillaria root disease was attributed to one species, Armillaria mellea. However, scientists now refer to an A. mellea complex, composed of approximately 10 distinct species which are differentiated based on morphological, biological, and ecological properties. While some species are purely saprophytic, decaying only dead wood material, there are a few host specific pathogens (a parasite capable of causing disease in a particular host or range of hosts). A. ostoyae is the species most often associated with Armillaria root disease of conifers in the Western United States.

Armillaria quickly invades the root system of infected trees when they are cut or killed. The pathogen survives for decades as a saprophyte on woody tissues of stumps and snags, which act as a food base. Spread occurs when healthy roots contact decayed roots, or by rhizomorphs (fungal strands of hyphae) which can grow through the soil for short distances and penetrate the bark of healthy roots. Armillaria attacks the roots and root collar of trees of all ages, killing the cambium and inner bark and causing a decay of both sapwood and heartwood. Rapid death occurs when the fungus advances rapidly through the inner bark and girdles the root collar.

The ability of Armillaria to kill trees is greatly influenced by host vigor. It is often very aggressive in young stands less than 30 years old. The advance of the fungus is much slower in older, rapidly growing trees, in which resin secretion and callus formation blocks spread of disease. During periods of drought, infected trees of all ages are often overcome. However, with a return to average or better moisture conditions, the rate of mortality of large infected trees nearly ceases.

Trees infected with Armillaria or other diseases are often predisposed to attack by cambium mining insects such as Dendroctonus bark beetles, Ips, and/or wood borers. Infestations often coincide with or immediately follow periods of subnormal precipitation.

Armillaria root disease can be called a "disease of the site," since the pathogen survives for extended periods of time in woody material and can infect susceptible regeneration on the site.

Annosus Root Rot, Heterobasidion annosum. Primarily found on pines and spruce in the Southwest. Annosus root rot can be a serious problem in plantations that have been thinned. Heterobasidion annosum is well adapted for rapid invasion of freshly cut stumps and is transmitted to living trees by root contacts and natural root grafts. Basidiospores are produced from fruiting structures, or conks, found in the root crotches or in duff around the base of infected trees. The fungus can exist for a long time as a saprophyte in buried roots and stumps. Symptoms are similar to other root pathogens: Dead and declining trees, alone or in groups; and windthrown trees with decayed roots. Control measures include: Treating the surface of freshly cut stumps with

borax or urea to prevent colonization; inoculating freshly cut stumps with highly competitive but nonpathogenic fungi; harvesting during the hot dry summer season when conditions are adverse to spore germination and infection; planting conifers in mixture with hardwoods; thin stands by girdling trees rather than cutting.

DWARF MISTLETOES

Southwestern Dwarf Mistletoe, Arceuthobium vaginatum subsp. cryptopodum.
Douglas-fir Dwarf Mistletoe, Arceuthobium douglasii.
Spruce Dwarf Mistletoe, Arceuthobium microcarpum. Dwarf mistletoes are the most damaging disease agents in Southwestern conifer forests. All dwarf mistletoe species are host specific, but the basic biology is similar. Dwarf mistletoes are parasitic, seed-bearing plants that depend on their hosts almost completely for their water and nutrients. The disease spreads by explosively released seeds which are expelled to distances ranging from 10 to 40 feet. Seeds are released from late July through September, depending on the species. Germination occurs in early winter of the same year as seed dispersal for southwestern dwarf mistletoe, but occurs the following year for Douglas-fir and spruce dwarf mistletoe. Infection takes place through the bark on needle-bearing portions of twigs. Dwarf mistletoes first produce an endophytic system, a specialized root-like structure that is in contact with the phloem and xylem of host trees, from which the parasite obtains most of its nutrients and water. The aerial shoots appear between two to five years after infection; this period of infection before shoots are visible is known as the latent period.

The disease causes mortality and growth reduction in infected trees: A decrease in the quantity, quality, and germination percentage of seeds produced; and lowers timber quality. Severely infected trees are more susceptible to attacks by insects and other diseases and to environmental stresses such as drought. Heavily infected trees (DMR = 5 or 6) may sustain a 20 to 50 percent reduction in growth when compared to uninfected trees and their life expectancy is severely decreased (Lightle and Hawksworth, 1973; Hawksworth and Geils, 1990). Dwarf mistletoe infects trees of all ages and is thus a problem in second growth and regeneration, as well as, mature and overmature stands.

Spread of dwarf mistletoes is a function of stand density, age, and site index, and averages one to two feet a year. Spread is most efficient and rapid from an infected overstory to an understory and slowest through an even-aged stand.

OTHER COMMON DISEASES OF CONIFERS

Schweinitzii Butt Rot, Phaeolous schweinitzii. One of the most common root and brown cubical butt rot pathogens in both natural and planted coniferous forests. Very common in old growth forests throughout the United States. In a study in the mountains of Arizona, it was associated with 66 percent of all storm broken butts of Douglas-Fir (Sinclair, Lyon, and Johnson, 1987). Most common hosts in the Southwest include: Douglas-fir, spruces, true firs, and western white pines. Most noticeable damage is as butt rot in mature trees, but the fungus attacks roots of any age and may enter the stems of young trees through roots or basal wounds. The fruiting body arises from the main roots of infected trees by means of a stalk. The fruit body is rusty yellow to brown.

The upper surface is tomentose or velvety from which it is called the velvet top fungus. It is also called the cow patty fungus because it is often mistaken for one. Phaeolous schweinitzii often enters damaged or perhaps dead superficial roots or wounds such as fire scars at the trunk base. However, wounds are not required. This pathogen has been reported to infect and kill root tips and induce swelling at the ends of the resulting root stubs of Douglas-fir. Roots previously colonized by Armillaria have also been suggested to be avenues of infection because the two pathogens are often associated and Phaeolous schweinitzii is capable of growing through wood colonized by Armillaria. The opposite scenerio has been observed in Idaho.

Red Belt Fungus, Fomitopsis pinicola. A significant heart rot pathogen, unique in that it commonly colonizes both angiosperms and gymnosperms. F. pinicola decays both live and dead wood, but fruiting bodies are typically produced only on dead trees and logging slash, so decay in living trees is difficult to identify. The most common gymnosperm host groups in the Southwest include Douglas-fir, true firs, and spruce. This is one of the most important brown rot fungi (fungi which decay cellulose but not lignin) of old-growth western conifers, but it acts slowly and is not considered a major decay pathogen of second-growth forests. It is an important member of the coniferous forest ecosystem because it decays dead trees and logging slash and leaves a lignin-rich residue that is very stable and a major component of the forest floor organic matter. The residue enhances water-holding and cation exchange capacities of soil and is a favorable habitat for the development of ectomycorrhizae and for nitrogen-fixing bacteria. The shelf-like to rounded basidiocarps have a red-brown band near the white to cream-colored edge. The fruit bodies are produced at wounds but it is not known if these are required for entry.

Red Rot, Dichomitus squalens (= Polyporus anceps). Red rot is the major decay of living ponderosa pine in the Southwest. Lightle and Andrews (1968) found that loss due to red rot in old-growth ponderosa pine on the Navajo Reservation in Arizona amounted to 15 percent of the gross volume. The fungus commonly fruits on the underside of fallen logs and dead limbs. The fruiting body is beige to yellow in color, flat, with pores from which the fungal spores are released. Bole infections arise from infected dead branches >1 inch in diameter with intact bark. The bark keeps moisture in the wood which aids fungal colonization. Pruning dead limbs of ponderosa pine in recreation areas will prevent D. squalens from infecting the bole.

INSECTS

Western Spruce Budworm, Choristoneura occidentalis. The western spruce budworm feeds on foliage of true firs (white fir and subalpine fir), Douglas-fir, and spruce throughout the Western United States. In the Southwest, its principal hosts are white fir and Douglas-fir (Linnane, 1986). During outbreaks, this moth causes considerable defoliation.

The budworm completes one generation per year. Adult flight and mating occur in late July to early August. Females lay eggs on the undersides of needles from late July through mid August. Following egg hatch, which occurs in about 10 days, the tiny caterpillars seek hiding places in limbs or the bole of their host. There they spin silken shelters called hibernacula and remain for the winter. In spring, larvae emerge and begin feeding. At first they mine buds or older needles. As larvae mature they feed on expanding buds and fully

expanded current years foliage. Mature larvae pupate in silken webs. Adult moths emerge in 10 days, completing the cycle.

Larvae feed primarily in buds and on foliage of the current year. Complete defoliation may occur if the outbreak persists for four to five years (Furniss and Carolin, 1977). Sustained heavy defoliation can result in decreased growth, tree deformity, top-killing, and death. Defoliation can also predispose trees to attack by bark beetles. Severe defoliation can affect visual quality.

Forest stands most susceptible to western spruce budworm are multi-storied with white fir and Douglas-fir predominating the overstory, densely stocked to overstocked, and mature with low vigor (Linnane, 1986). Similar stands of blue spruce, Engelmann spruce, and corbark fir are susceptible but to a lesser degree.

BARK BEETLES

Bark beetles are small cylindrically shaped insects which bore in the inner bark of their hosts. Most are fairly host specific. Bark beetles primarily attack trees weakened or predisposed by factors such as drought, disease, injuries etc., except during outbreaks. Methods that promote good growing conditions for hosts reduce mortality rates. Four species are of minor concern in the area surveyed.

Western Pine Beetle, Dendroctonus brevicomis. Western pine beetles attack ponderosa pine in the Southwest. Trees six inches and larger may be attacked (Demars and Roettgering, 1982). This insect most commonly attacks old trees, or younger trees if growing in dense stands. Trees recently hit by lightning, or heavily infected with southwestern dwarf mistletoe are also frequently infested. Two to four generations of beetles are produced per year. The beetles are active from late spring until the onset of cold weather in fall. Galleries are winding or mazelike in appearance. The best external evidence of infestation is the presence of pitch tubes on the bark surface.

Western Balsam Bark Beetle, Dryocetes confusus. The western balsam bark beetle attacks corkbark and subalpine firs in the Southwest. Its biology is not as well known as some other bark beetles. It is frequently observed in association with root disease centers. A one to two year life cycle is reported (Furniss and Carolin, 1977). Egg galleries consist of a central nuptial chamber with several egg galleries radiating out.

Spruce Beetle, Dendroctonus rufipennis. The spruce beetle attacks Engelmann spruce primarily and blue spruce infrequently in the Southwest (Schmid and Frye, 1977). It prefers downed material to standing trees, but when the former are unavailable standing trees may be attacked. Large diameter standing trees are preferred to small trees.

This insect has a two year life cycle. Adults attack in June and July and the first winter is passed in the larval stage. Development continues the second year and by the second winter the adult stage is reached. The adults emerge the following summer. Egg galleries are oriented parallel to the wood grain with a slight curve in the initial portion. Best external evidence is the presence of reddish-brown boring dust or occasionally pitch tubes on the bark surface.

Unmanaged stands of Engelmann spruce and subalpine fir may be rated for susceptibility to this insect using a system developed by Schmid and Frye (1976). Four stand characteristics: Average diameter of spruce, basal area, species composition, and physiographic location are used for rating. Potentially high risk stands would have an average DBH of greater than 16 inches, basal area of more than 150 square feet per acre, more than 65 percent spruce in the canopy and located in a well drained (good site) creek bottom. Low risk stands usually have an average diameter of less than 12 inches, basal area of less than 100 square feet per acre, less than 50 percent spruce in the canopy, and a site index of 40-80.

Douglas-fir Beetle, Dendroctonus pseudotsugae. Douglas-fir is the only host for this insect in this Region. Downed trees as well as standing trees are attacked. In the Southwest, outbreaks have been associated with western spruce budworm outbreaks. Greatest mortality occurs in dense stands of mature trees (Furniss and Orr, 1978).

One generation is produced per year. New attacks usually occur between April and June. Egg galleries run parallel to the wood grain and average 8 to 10 inches in length. Reddish-brown boring dust caught in bark crevices is good evidence of attack. No pitch tubes are formed but resin may stream from the attacks in the upper bole.

ASPEN DEFOLIATORS

Western Tent Caterpillar, Malacosoma californicum.
Large Aspen Tortrix, Choristoneura conflictana. Both of these moths are defoliators that feed on aspen in the Southwest. A one year life cycle is reported for both species. Larvae primarily feed in spring on aspen foliage. Western tent caterpillar larvae produce large silken tents in which they feed. Aspen tortrix larvae first feed within aspen buds in spring and later roll leaves into feeding shelters. Outbreaks of both insects are relatively short-lived and result in minor damage even though whole trees can be defoliated. Occasionally sustained outbreaks (four years or longer) of western tent caterpillar have resulted in tree mortality and top-killing (Jones et al, 1985).

MANAGEMENT CONSIDERATIONS

Recreation sites should be developed in areas where existing or potential insect and disease incidence does not conflict with management objectives. It is extremely important to consider the longevity of the site and projected hazard tree development. Managers must decide what pest infested areas to avoid (eg. a highly dwarf mistletoe infected stand) and when silvicultural treatments may alleviate pest problems, especially if visual quality or design objectives are enhanced. For example, root disease infected trees and their stumps can be removed from an area with a few small root disease centers. The cleared area can be used for an administrative center or parking lot. Another example is pruning and removing dwarf mistletoe infected trees in areas where infection is very light and the majority of the site is occupied by nonhost type trees. Control treatments to consider for the major pests found in the Big Lake Management Complex are offered below.

In the summer of 1990, Recreation Management personnel on the Apache-Sitgreaves National Forests met with staff from the Forest Pest Management Arizona Zone to review the results of our survey and select a general area for development of the campground. Consideration was given to the incidence and distribultion of disease in addition to campground design and construction criteria. As a result, an area within Stand 5 was selected and is shown in Figure 6.

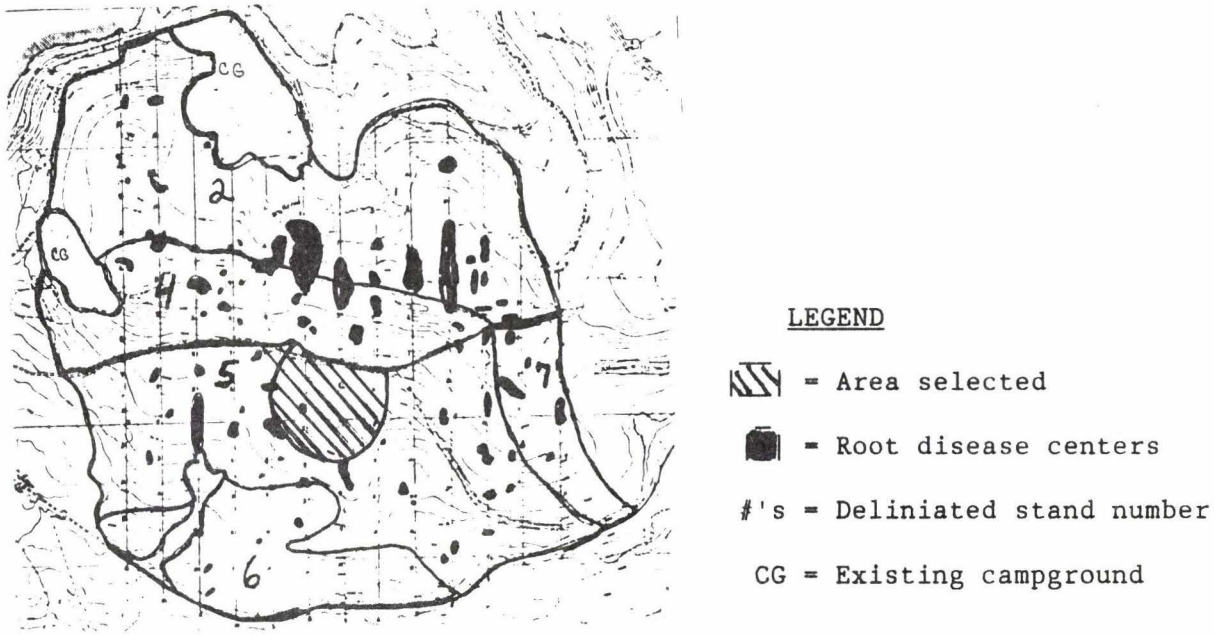

Figure 6. Preferred Area of Stand 5 for Campground Development.

Armillaria Root Disease

In southwest mixed conifer forests, a large proportion of tree mortality is attributed to root diseases and associated pests (Wood, 1983). Armillaria root disease can be called a "disease of the site," since the pathogen survives for extended periods of time in dead woody material and can infect susceptible regeneration on the site. Careful examination and mapping of infection centers in the Big Lake Management Complex was necessary to identify areas to avoid or in need of special treatment. The preferred area for campground development has a few small root disease centers.

Treatment recommendations are best directed toward limiting disease buildup or reducing its impact. Treatment options include: Minimizing stress to and wounding of residual trees; reducing the food base of the fungus by uprooting infected stumps; reforesting heavily infected stands with less susceptible conifers; and maintaining vigorous tree growth. It is best to avoid developing recreation sites in root disease infected areas. However, as mentioned above, small diseased centers (1 to 10 trees) may be cleared for administrative or parking areas, where the trees and stumps are removed. The disease may be found on trees 30 to 40 feet beyond the last visibly infected tree. A buffer zone should be treated along with the obvious infection center. Pathogenic Armillaria species do not colonize uninfected dead root systems, therefore, cutting a buffer strip of healthy trees should halt the spread of disease.

Pushing out stumps with heavy machinery may also be used to protect regeneration. Emphasis on less susceptible hosts such as southwestern white pine is recommended. Where the emphasis is on visual quality and not site development and aspens are adapted to the site, species conversion to aspen over the rotation allows Armillaria to die out in conifer roots and stumps.

DWARF MISTLETOES

The first step in management of dwarf mistletoe is to determine the level of DM acceptible to accomplish management objectives for a given area. Constraints such as costs, appearance of treatments, suitability of site, etc., are also considered. Dwarf mistletoe in developed recreation sites should be avoided. However, if the level of disease is low in a host species which represents a small percentage of the total trees per acre, treatment during construction may be considered. Followup treatments are required.

Treatments are typically directed toward decreasing spread and intensification of disease since dwarf mistletoe eradication is achieved only by removing the entire stand of trees. In timber emphasis areas, treatments include regeneration cuts, in which infected residuals are removed after stand establishment, and intermediate thinnings which remove the more heavily infected trees.

In recreation forests, pruning is an alternative treatment to decreasing infection and prolonging the life of valuable trees. The following suggestions for southwestern dwarf mistletoe control in recreational forests are offered based on a 20 year study in Grand Canyon National Park by Lightle and Hawksworth (1973):

- Pruning is recommended in lightly infected trees (DMR<3). Remove branches two whorls above highest DM-infected branch to insure against latent infections. No more than 50 percent of the live crown should be removed.

- Confine pruning to more isolated trees. Repruning has been required in densely stocked stands due to numerous latent infection in areas initially considered lightly infected.

- Infected branches should be cut off at the bole in order to insure removal of the root-like, endophytic system in the host tissue.

- Trees with bole infections do not need to be killed since bole infections are not vigorous.

- Pruning witches brooms on heavily infected trees (DMR = 3-4) does prolong life. A shorter life expectency corresponds to higher DMR.

Other management strategies include:

- Sanitize densely stocked stands. The most severely infected trees are removed to eliminate much of the inoculum and promote vigor of lightly and non-infected trees.

- Remove severely infected overstory trees. A vegetation management plan should be prepared for the recreation site in which long-term maintenance of tree cover is stressed; emphasize non-host species to eventually replace dwarf mistletoe-infected trees.

- Apply ethylene-releasing chemicals to promote abscission of dwarf mistletoe aerial shoots (Beatty, et. al., 1988; Nicholls, et. al., 1987). This method may reduce seed dispersal; the pathogen is not eliminated since the endophytic system remains viable within the host tissue and new aerial shoots continue to form, even the same year plants are sprayed (Johnson and Hildebrand, 1990). Research is in progress to assess the effects of this method for controlling dwarf misltetoe seed dispersal and protecting high value trees from becoming infected.

OTHER COMMON DISEASES OF CONIFERS

The same levels of root and stem decay desirable in old growth forests, create hazard trees which may lead to injury to people and/or damage to their property in developed recreation sites. Avoiding sites with extensive decay is one approach to this problem, however, investigations have shown that recreation use itself increases the incidence of root and stem disease fungi (Storozhenko, 1987). A preventive approach is desirable and would include: site construction which limits wounding; design which will limit soil compaction over tree roots; a plan to educate the recreationist on the consequences of injuring trees; pruning dead limbs of mature pine to prevent fungi from infecting the bole. Most stem fungi get established in limbs greater than one inch in diameter and are associated with older, mature trees.

ASPEN DISEASES

Developing campgrounds in areas where greater than 30 percent of the trees are aspen is highly discouraged. The life expectancy of a campground in an aspen grove is only 25 to 30 years (Hind, 1976) and costs of hazard tree removal are high. A recent study in New Mexico (Rogers, 1990), reported over 500 dead aspen trees in a 29-year-old developed site. The bark of aspen is very thin, making these trees highly susceptible to diseases and insects. Mechanical injuries sustained as a result of site construction and recreationists, and sunscald injury from stand openings (Walters, et. al., 1982), creates entry courts for disease causing fungi. These fungi are the main cause of mortality in aspen. An area with a small percentage of aspen can be utilized if the aspens are not located in high use areas.

We recommend a preventive approach to development of the campground in the Big Lake Management Complex and suggest a vegetation management plan for the entire area be developed. A preventive approach would, most importantly, include careful site selection which considers minimal pest impact. Avoiding areas with aspen as the dominant species is crucial.

REFERENCES

Beatty, J.S., H. Maffei, E. Collins, and M. Christian. 1988. Ethephon tests for ponderosa pine dwarf mistletoe in New Mexico. Proceedings of the 36th Western International Forest Disease Work Conference, p 39-40.

Demars, C.J., and B.H. Roettgering. 1982. Western pine beetle. Forest Insect and Disease Leaflet 1, USDA Forest Service, 8 p.

Furniss, R.L., and V.M. Carolin. 1977. Western forest insects. USDA Forest Service Miscellaneous Publication No. 1339. 654 p.

Furniss, M.M., and P.W. Orr. 1978. Douglas-fir beetle. USDA Forest Service Forest Insect and Disease Leaflet 5. 4 p.

Hawksworth, F.G. 1977. The 6-class dwarf mistletoe rating system. USDA Forest Service, Gen. Tech. Rep. RM-48. 7 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Hawksworth, F.G. and B.W. Geils. 1990. How long do mistletoe-infected ponderosa pines live? Western Journal of Applied Forestry 5:47-48.

Hinds, T.E. 1976. Aspen mortality in rocky mountain campgrounds. USDA Forest Service, Gen. Tech. Rep. RM-164. 20 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Hinds, T.E. and M.G. Ryan. 1985. Expansion of sooty-bark and ceratocystis cankers on aspen. Plant Disease 69:842-844.

Johnson, D.W., and D.M. Hildebrand. 1990. Effects of application rate and timing of ethephon treatments on abscission of ponderosa pine dwarf mistletoe two years following treatment. USDA Forest Service, Gen. Tech. Rep. R2-47. 9 p. Rocky Mountain Region, Lakewood, Colo.

Jones, J.R., N.V. Debyle, and D.M. Bowers 1985. Insects and Other Invertebrates. In: DeByle, N.V., and R.P. Winokur, eds. Aspen: Ecology and Management in the Western United States. USDA Forest Service General Technical Report RM 119. pp 107-114. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Landis, T.D. and A.K. Evans. 1974. A relationship between Fomes applanatus and aspen windthrow. Plant Disease Reporter 58:110-113.

Lightle, P.C. and S.R. Andrews. 1968. Red rot in residual ponderosa pine stands on the Navajo Indian Reservation. USDA Forest Service, Res. Pap. RM-37. 12 p. Rocky Mountain Research Station, Fort Collins, CO.

Lightle, P.C., and F.G. Hawksworth. 1973. Control of dwarf mistletoe in a heavily used ponderosa pine recreation forest: Grand Canyon, Arizona. USDA Forest Service, Res. Pap. RM-106. 22 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Linnane, J.P. 1986. Integrated forest protection guide. Western spruce budworm in the southwest. USDA Forest Service Forest Pest Management Report R-3 86-7. 22 p. Southwestern Region, Albuquerque, NM.

Nicholls, T.H., L. Egeland, F.G. Hawksworth, and D.W. Johnson. 1987. Control of dwarf mistletoe with ethephon. Proceedings of the 34th Western International Forest Disease Work Conference, p. 78-85.

Rogers, T.E. 1990. Biological evaluation of pest conditions and potential hazard trees occurring within the Canjilon Lakes recreation area. Carson National Forest, New Mexico. USDA Forest Service, R-3 90-6. 18 p. Southwestern Region, Albquerque, New Mexico.

Schmid, J.M. and R.H. Frye. 1976. Stand Ratings for Spruce Beetles. USDA Forest Service Research Note RM-309. 4 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Schmid, J.M. and R.H. Frye. 1977. Spruce Beetle in the Rockies. USDA Forest Service General Technical Report RM-49. 38 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Sinclair, W.A., and H.H. Lyon, and W.T. Johnson. 1987. Diseases of trees and shrubs. Cornell Uiversity Press. 574 p.

Stage, A.R. 1973. Prognosis model for stand development. USDA Forest Service, Res. Pap. INT-137. 17 p. Intermountain Forest and Range Experiment Station, Ogden, UT.

Stage, A.R., C.G. Shaw, M.A. Marsden, J.W. Byler, D.L. Renner, B.B. Eav, P.J. McNamee, G.D. Sutherland, and T.M. Webb. 1990. User's manual for western root disease model. USDA Forest Service, Gen. Tech. Rep. INT-267. 49 p. Intermountain Research Station, Moscow, Idaho.

Storozhenko, V.G. 1987. Fungus diseases in recreation forests. Lesnoe Khozyaistro. No. 3, Ru, 7 ref. VNILM, USSR.

Walters, J.W., T.E. Hinds, D.W. Johnson, and J. Beatty. 1982. Effects of partial cutting on diseases, mortality, and regeneration of Rocky Mountain aspen stands. USDA Forest Service, Res. Pap. RM-240. 12 p. Rocky Mountain Research Station, Fort Collins, CO.

Wood, R.E. 1983. Mortality caused by root diseases and associated pests on six National Forests in Arizona and New Mexico. USDA Forest Service, R-3 83-13. 31 p. Southwestern Region, Albquerque, New Mexico.

Wykoff, W., N.L. Crookston, and A.R. Stage. 1982. User's guide to the stand Prognosis model. USDA Forest Service, Gen. Tech. Rep. INT-133. 112 p. Intermountain Forest and Range Experiment Station, Ogden, UT.